Use of Low Resolution Satellite Imagery (LRSI) For Development of Building Inventory.

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Abstract:
Building or housing inventory plays basic role in the Seismic Risk Analysis (SRA). Housing census and type of building based on its construction type is an important aspect for seismic risk analysis. The housing census of Pakistan was done initially on the basis of population census 1998. The present housing stock has been estimated by extrapolation of the 1998 housing census at the population growth rate. This rationale is not logical as the temporal and spatial variation in the housing stock and extensive urbanization as well transmigration of large populations has complicated the scenario. The southern part of Pakistan (Baluchistan) province is more vulnerable to earthquakes. The non-availability of rational district-wise housing census is a major impediment to developing proactive disaster mitigation plan at district levels. In this research, a quasi-observational method has been used, incorporating the low resolution satellite imagery of Google Earth and field observations of some selected areas, to develop the district wise housing inventory. It has been observed that almost 85% of the houses are non-engineered houses constructed in mud, unreinforced brick masonry with mud mortar and rubble stone masonry, which are highly vulnerable to earthquake damages and risks. In such areas more proactive disaster mitigation strategies are required.

Keywords: Buildings, Inventory, Seismic Risk Analysis, LRSI, Online Google Earth®, Baluchistan, Pakistan

Introduction:

Disaster Management is the process of developing plans, processes, programs and policies to prepare, respond and mitigate damages associated with the natural and man induced disasters. The damages and collapse of buildings and other physical infrastructure lead to wide scale catastrophes and human casualties. In 2005, earthquakes of Kashmir and Northern Pakistan, a total of 85000 people were killed and a large number of buildings have been partially and completely destroyed. For proactive disaster risk analysis and management, proper building inventory showing the characteristics of the buildings, their typologies and temporal distribution is required. Users of building inventory methodologies include loss estimation modelers, government agencies, and various private-sector groups, including insurance companies, real estate organizations, and financial institutions**.** The traditional techniques for developing intelligent building inventory on the basis of field surveys and measurement are both costly and time consuming. Most of the building inventories are static because it rarely incorporates changes in the built environment on real time basis. The rapid urbanization in developing countries, on the other hand, further complicates the process due to fast growing temporal and spatial distribution of buildings. Regular revision and updating of these inventories are thus essential for the urban planning and disaster risk analysis.

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The Global Earthquake Model (GEM) Foundation initiated a research project, Inventory Data Capture Tools (IDCT), to offset the cost of field data collection for developing building inventories with the help of Open access tools supported with filed observations(Wieland M. et al 2012). The use of high resolution Satellite Images to detect the extent of buildings has been widely used by many researchers for high rise buildings (Miura H. 2006) (Sarabandi P. et al 2006) (Marangoz et al 2006). For a general building stock the following parameters affect the damage and loss characteristics: structural (system, height, and building practices), nonstructural elements and occupancy (such as residential, commercial, and governmental). Building taxonomies, typologies and associated categories are defined by various combinations of use, time of construction, construction material, lateral force- resisting system, height, applicable building code, and quality(HAZUS-MH 2003). An efficient and effective model incorporating the changes in the building stock over period of time (Spatial-temporal model) can help in developing proactive disaster management strategies in these countries (Calvi G.M. et al 2006). Various tools have been applied to solve this problem. These tools include remote sensing and satellite based imageries, which have been extensively used for pro and post-earthquake building damages. The use of High Resolution Satellite Imagery (HRSI) has been effectively used by many researchers in this context (Yonezawa 2001) (Gamba 1998).

Building Typologies and Statistics in Pakistan:

The building typologies in Pakistan have been classified as adobe, stone masonry, cement block masonry, brick masonry, reinforced concrete frames and timber, (ST Maqsood. J 2008). The mud houses are more dominantly used in Baluchistan province whereas stone masonry houses are common in Northern Province of Khyber Pakhtunkhwa (KPK). The brick masonry houses are more common in urban areas of the country and timber houses are adopted in rural areas of Pakistan. Further details of these various types of buildings are given as follows:

2.1. *Reinforced Concrete Frame (RCF)*

Reinforced concrete frames exist in urban areas as commercial units mostly. Their height varies from 5 to 6 storeys, however majority of such types of buildings are 3 to 6 storeys. These buildings are robust and resilient against earthquakes in general. The ductile behavior of the material gives it more resist to earthquakes. Such types of buildings are engineering buildings consist of Reinforced Cement Concrete (RCC) beams, columns, slabs and foundations combination. However due to high cost of construction, RCF is not very commonly used in the country.

2.2. *Reinforced Concrete masonry Infill (RCI)*

Reinforced concrete masonry infill exists almost in large numbers in urban areas. These buildings consist of 3 to 6 storeys. Most of the buildings are non - e n g i n e e r e d and more vulnerable than the RCF due to lack of detailing, poor quality of construction and materials. Construction involves brick masonry along with confined beams and columns combination; brick masonry here acts as load bearing walls. The earthquake performance of the RCI buildings remained below the standards.

2.3. *Unreinforced Brick Masonry- Cement Mortar (UBM-CM):*

These types of buildings are more common in study region for residential purpose. Brick Masonry with cement-sand mortar (CSM) is used for this type of buildings. Such types of buildings are up to 3 storeys with RCC roofing. Due to lack of ductile behavior, these buildings are more vulnerable to earthquake damages. The material is mostly brittle in nature and hence the earthquake behavior of the building is not good.

2.4. *Unreinforced Brick Masonry- Mud Mortar (UBM-MM):*

These buildings are commonly used in study region for residential purposes. Brick Masonry with Mud mortar (MM) is used for this type of buildings. Such types of buildings are single storey with timber and girder roofing, more affected by earthquakes. This type of buildings again is more vulnerable to earthquakes and its associated damages.

2.5. *Rubble Stone Masonry:*

Rubble stones for construction of residential buildings mostly exist in rural areas. In rural areas people use locally available stones without dressing. In foundation cement-sand mortar (CSM) is mostly used, while in super structure mud mortar (MM) is used. Timber roof with mud plasters are normally used for roofing. Due to heavy loads of walls and roofs, such buildings are highly exposed to earthquake damages. Due to brittle nature of the material used stone masonry, more casualties have been witnessed in such kinds of buildings during earthquakes.

2.6. ***Adobe/Mud buildings:***
These are low cost buildings incorporating local material and indigenous expertise. Such types of buildings predominantly exist in rural areas while scarcely in urban areas. Construction comprises of mud walls i.e. mud bricks with mud mortar for binding with Timber roofing, or girder roofing. During earthquakes of 2008 in Baluchistan the mud houses have been severely damaged (Shah Attaullah et al 2012).

The building statistics in Pakistan are based on the Population Census in 1998 conducted by Population Census Organization(PCO 1998). (Maqsood S T. Schwarz. J 2010) used the 1998 census to derive various types of houses in urban and rural areas in different regions of Pakistan . (PMD-NORSAR 2012) in their study for Earthquake Risk Assessment of Quetta (single district of Baluchistan) developed building inventory for Quetta city. Figure 2.

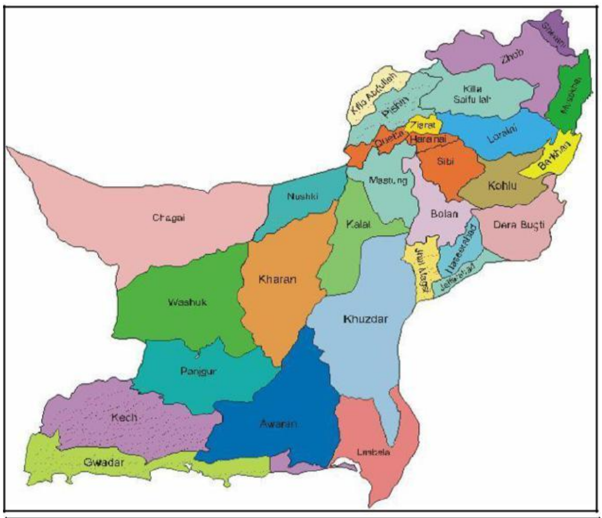


Figure 1: District Map of Baluchistan province Pakistan (Government of Baluchistan)

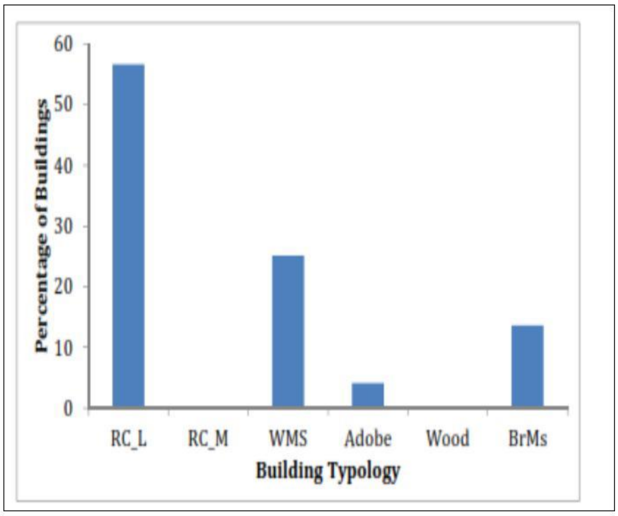


Figure 2: Building Inventory for Quetta 2012. PMD/NORSAR

The building inventory for Pakistan has not been revised or updated on the basis of actual development of houses and other physical infrastructure. Due to non-availability of latest building inventory in the country, the risk analysis associated with various disasters cannot be ascertained and hence a proactive Disaster Mitigation Plan cannot be developed. The building inventory is also essential for Earthquake Risk Analysis (ERA) in particular, as the buildings are causing heavy damages in earthquakes.
The southern part of Pakistan (Baluchistan) (fig 1) is also seismically active and there have been major earthquakes in the regions during last 100 years. Majority of the houses are constructed in mud/adobe. In 2008, North East districts of Baluchistan Province (Pakistan), Ziarat, Pashin and Harnai were hit by an earthquake of magnitude 6.4. As a result 170 people died, 173 injured and 9774 houses collapsed or damaged in this earthquake. The non-availability of latest building inventory of the province, on one side, and the vast territorial extent of the province spreading over an area 347190 Sq. Km, on the other side, makes it a real challenge to develop reliable building inventory to deal for realistic Earthquake Risk Analysis. The latest initiatives for developing Disaster Management Plan at district level, would require the housing typologies and distribution at the district level (NDMA 2007). The density and distribution of various housing typologies in different parts of the province are essential for this purpose. This research has been undertaken to develop building inventory incorporating various types of buildings in different districts of the province and compares it with the projection on the basis of 1998 housing census.

Research Significance:

Due to high vulnerability of Baluchistan province to natural disaster like earthquake and floods, the associated level to risk is also very high. For developing realistic Earthquake Risk Analysis at different districts, building inventory incorporating the housing typologies is essentially required. This study will provide the base for updating and revising building inventories on real time basis.

4. Research Methodology:

Step 1. Grid Distribution:

Digitized map of the study area was obtained from Department of Geological Survey of Pakistan (GSP). Initially digitized spatial map was divided into progressive grids in a Geographic information system. Grids were followed in a series of 33x33, 10.24x10.24, 7.61x7.61, 4.60x4.60, and 2.89x2.89 and 1.5x1.5 sq. km rectangular grids. A sample grid of 33x33 sq.km is shown in Fig 4.

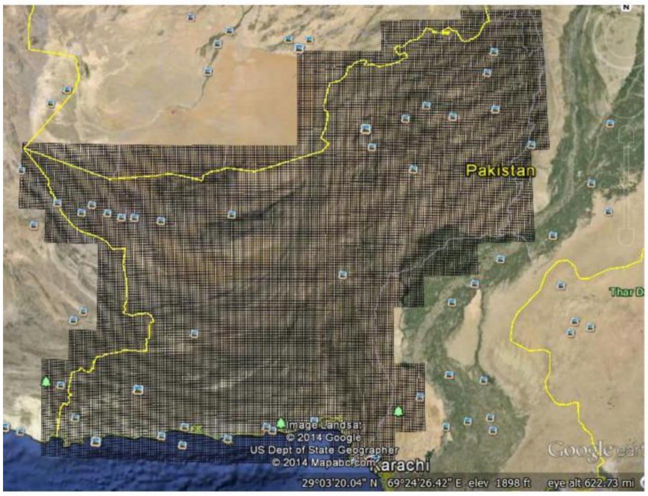


Figure 4: Importing Grids in Google Earth ®

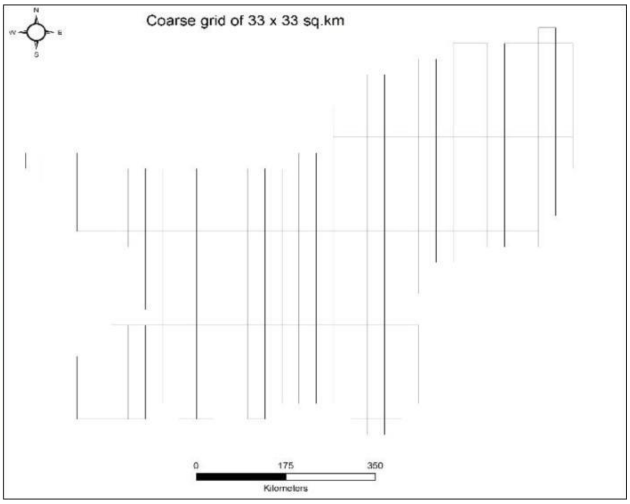


Figure 3: (Dividing Study area in Grids

Step 2. Importing Digitized Grid Map:

Progressively digitized grid map was imported to Google Earth ®. Google Earth ® is a computer tool which provides free Low resolution satellite images online. Here careful observation of attributes in each grid was carried. Observed data was stored in a manual data base. Initially in coarse grids larger area was covered and each grid was separately marked with graded codes to differentiate built and unbuilt area. A sample of grid imported to Google Earth ® is shown in Fig 3.

Step 3. Sampling.

Sample grid cells of each size of grids were created immediately after step 2. Sample grids comprised of satellite most possible zoomed view of various classes of buildings. These samples were used for observations of other grids. Sample grids were validated with actual site conditions. For identification of housing typologies at various parts of the province, field observations and feedback from Engineers in the field offices at randomly selected places were carried out Field observations consist of author's physical visit to some random places of Baluchistan and a greater part of such observations were covered using Google earth images uploaded by random Google earth users. The housing type in a particular cell was compared with the Standard Template Cells (STC's). 78 STC's consists of various template grids obtained as a result of zooming in various grid cells and differentiating types of buildings, construction material, density, structural details, nature of construction etc. A sample of STC is shown in Fig 6.

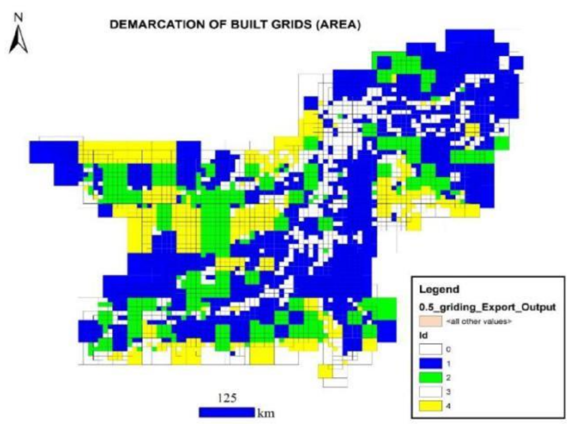


Figure 5: Eliminating Built and Unbuilt areas

Figure 6: Differentiating various Building Classes

Step 4. Separating Built and Unbuilt area.

Through carful observations using sample grids unbuilt area was initially targeted in each progressive grid. Since the province is comprised of large tracts of mountains and deserts, therefore the uninhabited areas are gradually excluded by the most possible clear zooming of each grid from ground. The iterative process enabled to develop the map in Fig, showing the mountainous uninhabited areas (blue), Plain uninhabited areas (yellow) and combination of the two (green). The white grids show the areas with buildings shown in Figure 5 .

Step 5. Categorizing Final Data.

By careful comparison of the built up area under each white grid, the typology of the houses in various districts of the province was categorized and noted.

Step 6. Data Validation.

Pakistan Census Organization proposed an equation in order to project the census of 1998 for any future period as census in the study area is not possible due to law and order situations after 1998. T hus housing census of 1998 was projected with the procedure explained by Pakistan Census Organization for extrapolating the population (Table 6). The actual housing census based on present method was compared for various districts of the province.

To validate these observations from actual field conditions, one of the authors was remained at study area for several years. Observed data was checked with actual site conditions considering small town and getting facts of building typologies.

Risk Assessment Model:

The building inventory development which is an important parameter for seismic risk assessment will be used for assessment of building risk due to an earthquake as result of seismic hazard assessment. ERA framework developed by (S.A. Khan & K. Pilakoutas 2012) will be used for hazard and risk assessment which is a computer tool developed for developing countries.

6 Observations and Discussions:

The basic housing information was obtained from population census of 1998. A formula is suggested by Federal Bureau of Statistics Pakistan, was used to project the population in various districts of Baluchistan province:

The census of houses available with Pakistan Population Census 1998, we also used to project the various housing typologies in different districts of Baluchistan province, with the assumption that the housing priorities and choice of housing types and material would remain unchanged. The district wise basic 1998 and projected housing typologies as of today are given in the Table 1 for various types of houses which is not an accurate method for estimating total number of available buildings types in study area.

Table 1: Projected Houses and their typologies in various districts of Baluchistan based on 1998 housing census.

Projected housing Typology based on 1998 Census							
District No.	District	Total Number of Building types					
		Pacca			Semi Pacca		Kacha
		RCF	RCI	UBM-CM	UBM-MM	Rubble Stone Masonry	Adobe
1	SIBI	0	131	1172	1449	0	18938
2	MUSAKHEIL	0	0	1875	949	406	7309
3	JHAL MAGSI	0	0	297	1328	0	23047
4	JAFFARABAD	98	98	9651	11727	0	74216
5	MASTUNG	0	0	512	653	283	12417
6	SHEERANI	0	0	1116	158	68	1369
7	HARNAI	20	40	1901	2343	0	12852
8	LORALAI	95	189	1579	2863	0	34517
9	QUETTA	624	1240	60173	19012	2198	52573
10	GAWADAR	63	128	6148	8116	903	17804
11	LASBELA	142	284	13725	16533	0	36756
12	QILLA	0	213	4007	1285	552	27803

SAIFULLAH

13	DERA BUGTI	59	0	5895	12034	0	23043
14	KOHLU	78	0	1491	5772	2474	10924
15	QILLA ABDULLAH	64	317	5956	7053	0	93048
16	CHAGAI	0	100	3190	2668	0	33754
17	KHUZDAR	15	48	1617	4604	0	58551
18	PANJGUR	20	41	1978	13744	0	40834
19	BOLAN	13	26	1344	1037	446	32099
20	KHARAN	0	0	1746	1610	0	22249
21	PISHIN	44	229	4301	5707	0	66020
22	ZIARAT	13	63	1189	1033	0	8980
23	BARKHAN	39	76	3727	2798	0	16482
24	KECH	0	194	5109	13533	5797	64843
25	NOSHKI	0	0	236	218	0	8765
26	ZHOB	0	263	12911	1238	532	9513
27	AWARAN	0	2	85	3318	0	8925
28	KALAT	10	22	1129	1942	0	32429
29	NASIRABAD	471	942	45629	24459	10485	285467
30	WASHUK	0	0	59	701	0	4073
	Total	**1868**	**4646**	**199748**	**169885**	**24144**	**1139600**

Pacca: (masonry or reinforced concrete, literally meaning baked) and Kacha (adobe, literally meaning unbaked)
RCF: Reinforced Concrete Frame RCI: Reinforced Concrete Infill Masonry UBM-CM: Unreinforced Brick Masonry- Cement Mortar UBM-MM: Unreinforced Brick Masonry-Mud Mortar

LRSI is, a technique, adopted in this paper can be used for developing countries only where access to HRSI is costly and logical. Total number of building types available in the study area using LRSI (present study) is shown in Table 2.

Table 2: Houses and their typologies in various districts of Baluchistan based on proposed method.

District wise Building inventory using present method							
		Building type					
District No.	**District**	**Pacca**			**Semi Pacca**		**Kacha**
		RCF	**RCI**	**UBM-CM**	**UBM-MM**	**Rubble Stone Masonry**	**Adobe**
1	SIBI	0	0	5950	3963	0	16965
2	MUSAKHEIL	0	0	5365	4920	0	7780
3	JHAL MAGSI	0	8	6675	535	0	15090
4	JAFFARABAD	0	126	14894	12836	2550	37151
5	MASTUNG	74	0	1208	2213	595	21140
6	SHEERANI	0	0	605	806	0	2185
7	HARNAI	24	0	700	1667	0	4105
8	LORALAI	10	8	22520	29320	0	35380
9	QUETTA	1626	2955	116482	99040	681	164342
10	GAWADAR	1	130	11744	7937	113	18901
11	LASBELA	49	2429	22264	13808	0	25631
12	QILLA SAIFULLAH	100	80	7720	10735	269	30898
13	DERA BUGTI	30	10	17909	8956	0	46725
14	KOHLU	24	0	935	5098	1943	5928
15	QILLA ABDULLAH	71	111	7566	16473	10538	70954
16	CHAGAI	8	203	2391	3222	1040	80961
17	KHUZDAR	8	105	14917	8302	4690	113921
18	PANJGUR	2	6	2221	1576	0	87176
19	BOLAN	18	5	1729	3310	264	26363
20	KHARAN	0	0	1198	1254	0	18531
21	PISHIN	126	83	10387	17666	290	62928
22	ZIARAT	2	10	1348	3256	0	8383
23	BARKHAN	12	22	1209	1303	0	14046

24	KECH	0	204	5519	5793	1335	193459
25	NOSHKI	30	0	5365	13082	170	28529
26	ZHOB	0	164	19714	3156	9389	33378
27	AWARAN	0	57	2717	4085	0	54905

28	KALAT	223	146	16733	9932	205	47452
29	NASIRABAD	464	1280	22852	10940	12811	33211
30	WASHUK	0	5	1863	1407	125	44338
	Total	**2902**	**8147**	**352700**	**306591**	**47008**	**1350756**

RCF: Reinforced Concrete Frame, RCI: Reinforced Concrete Infill Masonry, UBM-CM: Unreinforced Brick Masonry-Cement Mortar, UBM-MM: Unreinforced Brick Masonry-Mud Mortar

The comparison of the projected housing typologies on the basis of 1998 census and present method in Baluchistan province is given in Figure 7.

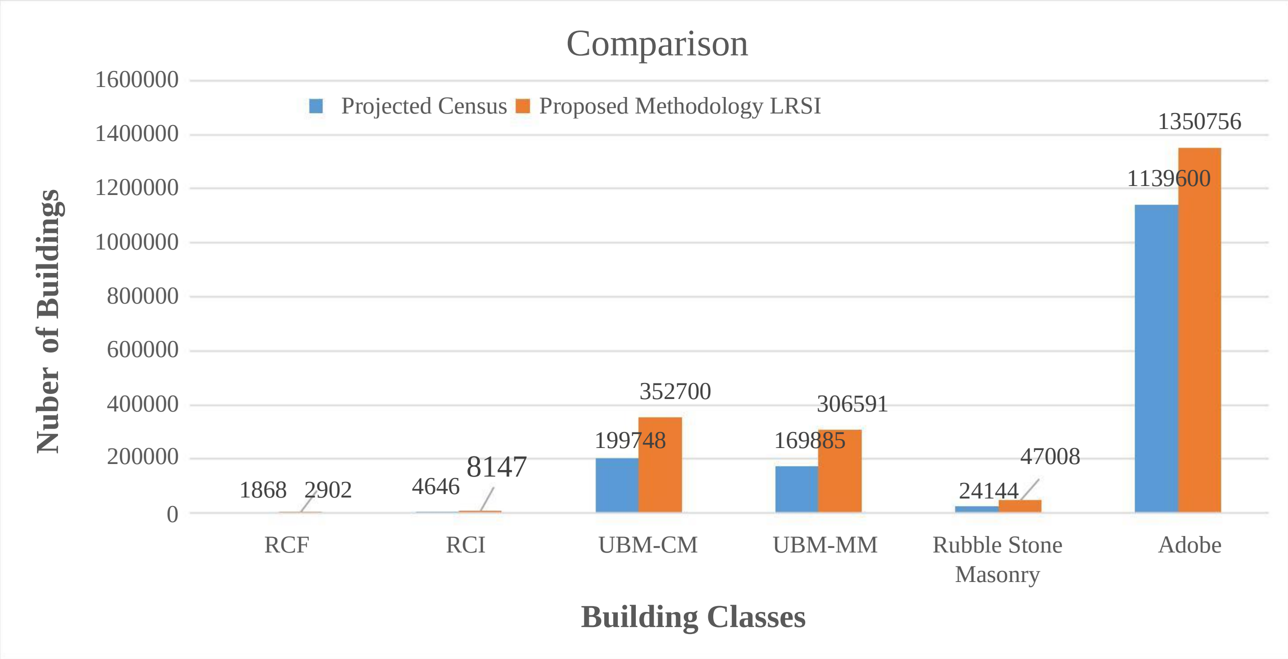
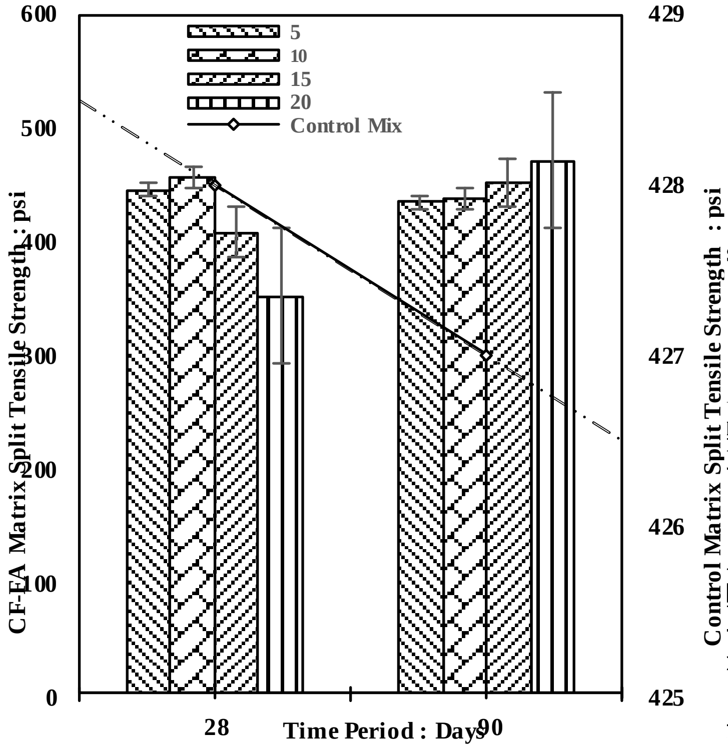


Figure 7: Comparison between total numbers of housing typology based on present method and Projected Census on basis of 1998 census.

The comparison of 1998 census based projection and present study shows very contrasting differences. This difference can be attributed to the fact that the 1998 housing census was not based on actual counting and field based observations and it was assessed on the basis of average occupancy, whereas the present study is based on more scientific information incorporating Satellite images and supported with field observations. The latest housing inventory reveals the following facts:

1. There is exponential increase in the housing stock due to population increase, on one side, and more fragmented family structures, on the other hand. The heavy influx of Afghan refugees and immigrants from Iran has further increased the houses density. The total housing stock is supposed to be 2 million for an estimated population of 10 million, thereby making the occupancy of 5 persons per house. This also reflects the low housing density of the province at 4 houses per sq. Km and population density of 20 persons per sq. km.
2. About 2/3rd. of total housing stock is comprised of mud houses, evenly available in all parts of the province. Unfortunately, the seismic performance of mud houses remained very poor in the previous earthquakes in the region. Thus people living in the 65% of the total houses are exposed to high level of seismic risk.
3. The next highest category of housing comes from Unreinforced Brick masonry in cement mortar (17%) and Unreinforced Brick masonry in mud mortar of the total building stock (15%).
4. The mud houses and Unreinforced Brick masonry in mud mortar constitute 80% of the total housing stock, which is relatively more vulnerable to seismic risks.
5. The houses in rubble stone masonry are merely 2.2% of the total, which are not large proportions.
6. The reinforced concrete based houses are only 5% of the total houses, which are relatively better in seismic performance. This means that 95% of the housing stock is relatively more vulnerable to seismic risks.



province developed in this research may be used for
s of the province.
risk assessment of the study area as explained in section 5.

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